Acta Oecologica 49 (2013) 1–4

Contents lists available at SciVerse ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Responses of a small-mammal community to habitat management through controlled burning in a protected Mediterranean area

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ARTICLE INFO

Article history:
Received 5 November 2012
Accepted 1 February 2013
Available online

Keywords:
Apodemus sylvaticus
Crocidura russula
Doñana National Park
Ecotone generation
Eliomys quercinus
Iberian Peninsula
Mus spretus
Scrub management

ABSTRACT

Fire is widely used as a management tool to achieve conservation goals. However, the consequences of such management on non-target species are frequently neglected and unknown. This study examines the effects of traditional management practices of scrubland clearance by controlled burning to improve menaced carnivores on non-target species: rodent and insectivores in Doñana National Park (SW of Iberian Peninsula). We used capture–recapture methods to examine changes in abundance in areas that were burnt one and three years ago, compared with unburnt areas. Results showed that burnt areas had higher species abundances, but mainly on the ecotonal boundaries. Species abundances showed dramatic seasonal differences with high abundances in autumn and winter, and very low abundance in summer. Our study revealed that scrubland management by controlled fires increases the abundance of small mammal species, mainly *Mus spretus* and *Apodemus sylvaticus*. We found only four small mammal species between the different treatments. However, some species that were formerly abundant in Doñana, such as *Elyomis quercinus*, were found only in burnt areas. Our results suggest that controlled burning is not contributing to the current loss of biotic diversity in this community.

1. Introduction

In most of Europe, small mammals are an important part of the terrestrial food web because they are prey species that affect the abundance and diversity of predator species (Butet and Leroux, 2001; Butet et al., 2006; Salamolard et al., 2000). In Iberian Mediterranean ecosystems, small mammals have historically played a secondary role in vertebrate food webs (Cagnin et al., 1998; Kufner, 1986) to that of the wild rabbit (*Oryctolagus cuniculus*), which is a keystone species for the conservation of more than 30 predator species (Delibes-Mateos et al., 2008), including two highly endangered species, the Iberian lynx (*Lynx pardina*) and the Iberian Imperial eagle (*Aquila adalberti*) (Ferrer and Negro, 2004). Currently, vertebrate food webs could be altered because rabbit populations on the Iberian Peninsula have crashed in the last four decades due to the effects of disease, habitat loss, overhunting and climatic variation (Delibes-Mateos et al., 2009a; Ward, 2005). Despite the fact that some rabbit populations have recovered in the last few years, rabbits are still scarce in most of the protected areas (Delibes-Mateos et al., 2009b), especially in Doñana National Park SW Iberian Peninsula (Moreno et al., 2007). Doñana N.P. supports one of the most dense and diverse predator communities in Europe (Kufner, 1986; Valverde, 1958, 1967). It also has one of the remaining two isolated populations of Iberian lynx (Garrote et al., 2011). Since 1989, habitat improvements, by controlled fires of Mediterranean scrubland, have been carried out in Doñana N.P. to create a mosaic of heterogeneous landscape to increase the abundance of wild rabbits (Moreno and Villafuerte, 1995), which are the main prey of the Iberian Imperial eagle and Iberian lynx (Román and Palomares, 2006). This management increases the abundance of rabbits and should have a direct impact on other animal species, in particular the small-mammal communities (insectivores and rodents) that are characteristic of scrubland habitats (Camacho and Moreno, 1989; Moreno and Kufner, 1988). However, no studies have been carried out to assess the impact of controlled fires on the small-mammal communities that live in the scrubby habitat of Doñana N.P. Changes in small-mammal communities can also be important if they become the alternative target prey for predators – which has occurred since the reduction of the wild rabbit populations. Thus, our aim was to analyse the effects of the burning management practice being carried out in Doñana N.P., and to evaluate changes in the species abundance and space-time

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http://dx.doi.org/10.1016/j.actao.2013.02.001

distribution of insectivore and rodent communities in Mediterranean scrub habitats.

2. Material and methods

2.1. Study area

Our study was conducted in Doñana National Park (0–100 m a. s. l.) located on the South–West coast of the Iberian Peninsula (37° N, 6°20′ W) (Fig. 1). The climate is Mediterranean with hot dry summers (average temperature in August 25 °C) and wet mild winters (average temperature in January 10 °C, average annual precipitation 600 mm). The total area of the park is about 53,700 ha, and there are three main biotopes: marshlands (c. 32,000 ha), mobile sand dunes (c. 5000 ha) and scrublands (c. 18,500 ha) (Rogers, 1974; Valverde, 1958). Marshlands are influenced by seasonal flooding, and sand dunes are affected by the mobility of the substrate. The scrubland, located between dunes and marshlands, is dominated by Mediterranean scrub formations (mainly *Halimium* spp., *Cistus* spp., *Ulex* spp., *Stauracanthus genestoides* and *Rosmarinum officinalis*), and is typical habitat for most small-mammal species. Since 1989, in this area more than 1200 plots ranging between 0.5 and 5 ha of dense and ageing scrubland have been burned (Moreno and Villafuerte, 1995).

2.2. Data collection

We selected nine plots similar in size (patches of about 1 ha), vegetation structure, distance to marsh and height above sea level (Fig. 1). From Summer 2006 to Spring 2007, capture-mark-recapture methods were carried out in areas where scrubland clear-cutting and controlled burning was performed according to a traditionally prescribed design (Moreno and Villafuerte, 1995). Three plots were located in non-burnt habitats ("control" plots), three were located at sites where scrub had been removed in Winter 2006 ("1 year burnt" plots) and the other three were located at sites where scrub had been removed in Winter 2003 ("3 years burnt" plots). Plots were separated by at least 1 km to ensure independence – thus there was no interchange of small mammals between sites.

A grid of traps ($N = 50$) was set up on each of the nine plots, with traps 15 m apart (Fig. 1). Live traps (Shermann) were baited with bread soaked with used fish-oil and placed at each grid intersection. In the six burnt plots ("1 year burnt" and "3 years burnt"), 25 more traps per plot were placed at the edge of non-burnt scrubland surrounding the burnt zone (Fig. 1). Thus we obtained two more treatment types, "edge 1 year" and "edge 3 year", respectively. Each plot was trapped once per season (summer, autumn, winter and spring) for seven consecutive nights between July 2006 and March 2007. Traps were set just before sunset and checked within 2 h after sunrise the following morning. Captured small mammals were marked (using individual subcutaneous transponders; Avidesp, Barcelona), weighed, measured and sexed. External reproductive signs were also noted. Animals were immediately liberated in the same place as they were captured and were available for recapture on subsequent nights.

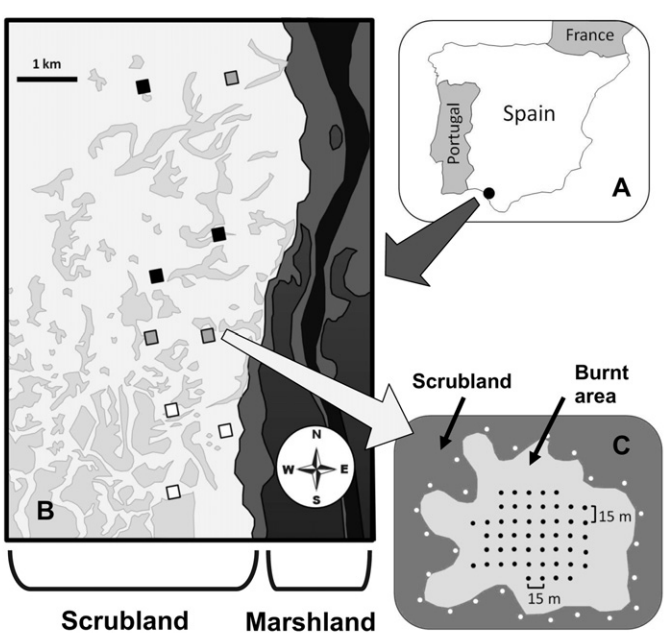

Fig. 1. (A) Location of Doñana National park (●) on the Iberian Peninsula. (B) Sketch of the distribution of study plots (squares: black "1 year burnt" and grey "3 years burnt" treatments; white "control" plots). (C) Example of distribution of the sampling units in a burnt plot (black: burnt-plot traps; white: edge-plot traps).

2.3. Data analysis

Seasonal relative abundances of small mammals were estimated as the number of individual animals from each species captured per 1000 trap nights. Recaptures in the same season were not included in the analyses.

To evaluate differences in relative abundances of species between the treatments we used generalized linear mixed models, using the procedure GLIMMIX within SAS version 8.2 (Littell et al., 1996). We normalized the data and fitted "relative abundance" to a normal distribution with an identity link function. The fixed factors were "treatment" (five levels: "1 year burnt" plots, "1 year edges", "3 years burnt" plots, "3 year edges" and "control" plots), "species" (three levels; three captured species, *Eliomys quercinus* was excluded due to the small number of captures; see Results section) and "season" (three levels; Autumn 2006; Winter 2006 and Spring 2007; Summer season was excluded due to the small number of captures in that period; see Results section). Plot (nine levels) was included as a random variable in the model. Due to the strong effect found for the "species" variable (see Results section), we carried out the same analysis detailed above but for each species independently. Additionally, Tukey's HSD (honestly significant difference) test was applied to evaluate differences in relative abundances between the treatments for each species.

Fixed and random variance components were calculated using procedure VARCOMP (SAS Institute Inc., 2002). Degrees of freedom in the denominator were estimated using Satterthwaite's formula (Littell et al., 1996). Model selection was performed in accordance with the 'top-down strategy' of Zuur et al. (2009). In these tests, selection of the best model was carried out by starting with the maximal model, and sequentially removing the effects farthest from statistical significance, starting with the highest order interactions. Q–Q normal plots were used to assess normality, and residuals from the models were plotted against fitted values to assess heterogeneity.

3. Results

During 16 425 trap nights, a total of 717 individual animals were captured, belonging to four species: three rodents – the wood mouse (*Apodemus sylvaticus*), the Algerian mouse (*Mus spretus*) and the garden dormouse (*E. quercinus*) – and one insectivore – the greater white-toothed shrew (*Crocidura russula)*. Animals caught per species ranged from 619 (*M. spretus*) to 2 (*E. quercinus*). *M. spretus*, the most commonly trapped species, accounted for